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SUB-IRRIGATION

—IN THE—

GREENHOUSE.

BY F. WM. RANE.

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SUB-IRRIGATION IN THE GREENHOUSE.

F. Wm. Rane, M. S.

During the past few years, this subject has invited more or less attention. It was not until the past winter, however, that special investigation has revealed its true value.

Personal interest in this subject was awakened through association with Prof. W. J. Green, Horticulturist of the Ohio Agricultural Experiment Station, who was the first to recommend it to the public. Interest was furthered by observations made through experimentation during the winter of '91-'92 at the horticultural forcing-houses of Cornell University. In the latter place, a small greenhouse apartment was equipped especially for carring on experiments along this line. Unfortunately, no complete, tabulated data were procured on account of the burning of the plants, by neglect in smudging, one night towards the terminus of the experiment.

When constructing new forcing-houses at the Station here last fall, special arrangements were made for continuing the experiment in order to detemine, if possible, its value.

"Sub-irrigation." This compound word is derived from the Latin preposition "sub," which means under or below, and "irrigation," from the Latin "irrigatio," a sprinkling, a watering Sub-irrigation, therefore, is a sprinkling or watering from underneath the soil.

The effects of sub-irrigation upon plant growth in the greenhouse were first brought to notice when experimenting towards some efficient means of checking or exterminating the disease known as rot in lettuce. The truth or falsity of the theory that "frequent watering in the ordinary manner induces the disease" was arrived at by arranging to supply the plants with the requisite amount of water from beneath. Watering in this manner through punctured pipes or porous tiles, which were underneath the soil, was at that time thought to be by no means a decided success in exterminating the lettuce rot; however, marked results were noticeable in that the sub-irrigated beds were more productive in vegetation than those watered in the ordinary manner.* From this as a starting point, the history of sub-irrigation in the greenhouse begins. Outside of those pursued in Ohio, we know of no other experiments undertaken in this line of investigation except our own.

*See Ohio Bulletin, Vol. V., No. 6, page 101.

The experiments at Cornell University were conducted in two beds, each 8 feet long by 3 feet wide, containing close-fitting bottoms. In one of the beds, one-inch iron pipe was coiled as in the cut.

This pipe was punctured on the sides at intervals of eight inches, in order to distribute the water The other bed was used as a check to the first, and was watered on the top in the usual way. Soil to the depth of six inches was placed in each bed, and plants of various structures were similarly planted in rows in the two beds.

Plants were selected with reference to their individual nature. As examples of those plants, the foliage of which is the part desired, lettuce and spinach were selected. As plants for root development, radishes and beets were taken, and those grown for their blossoms, daisies and sunflowers.

Up to the time the plants were destroyed, the results showed a marked difference in many respects. Some of the points particularly evident in favor of sub-irrigated beds were:—

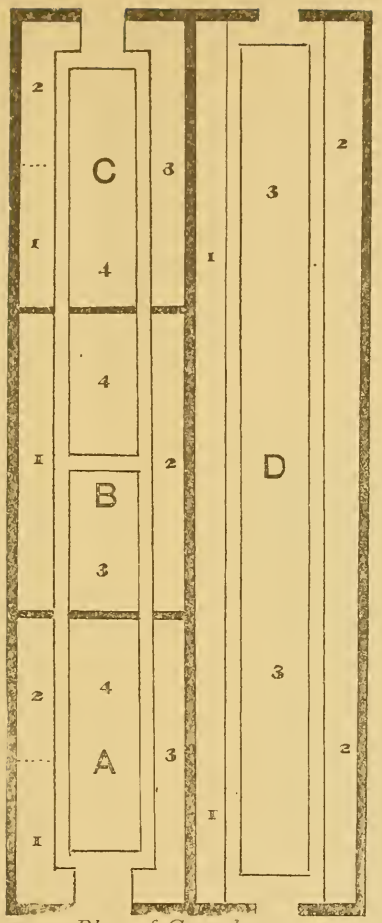
(1) A greater uniformity of growth.
(2) A great saving of labor in watering.
(3) Drying up of the under leaves instead of their becoming slimy and decayed as in surface watering.
(4) Easy cultivation of the soil.
(5) A more luxuriant growth.

Earliness in maturity of lettuce and spinach was noticeable. There was no perceptible difference in the growth of the radishes and beets, which were of the turnip-rooted varieties. Daises and sunflowers were much in advance in the sub-irrigated bed.

Experiments at the Station.

During the past winter, three beds were arranged for sub-irrigation, one in each of three houses of the following dimensions:

House A, 9 feet 6 inches by 3 feet 6 inches; house B, 6 feet 6 inches by 8 feet 9 inches, and house C, 9 feet 6 inches by 3 feet 6 inches. Each bed was made perfectly water-tight by the use of matched material. In the bottom of these beds was laid one and one-fourth inch pipe with punctures on the sides four inches apart.



Plan of Greenhouses.

Beds in houses A and C contained iron pipes arranged for watering in the following manner. Two parallel pipes were placed in the bottom twenty-one inches apart, and connected by elbows at one end, making them continuous. Of the two opposite ends in house A, one was closed by a cap, while the other was run up perpendicularly for at least two inches above the soil or top of the bed. See cut. In house C, instead of capping one of the opposite ends of the pipe, both were left open and carried above the surface of the soil by the use of elbows, as in house A.

The bed in house B contained lead pipe, which was easily adjusted to the desired position on account of its flexibility. It was placed similarly as in the other beds. Since the bed was much wider, three parallel pipes instead of two were placed with the ends protruding above the top of the bed at opposite corners. Instead of

leaving one continuous pipe, the central parallel was cut in the middle, and the ends hammered together and soddered, thus forming two pipes.

The punctures through which the water emerged from the pipe were four inches apart, and made with reference to as even a distribution as possible. This was accomplished to some degree by drilling holes low down on the sides of the pipe at the further end from where the water was poured in, and gradually raising them towards the other end, making the last one drilled come near the top of the pipe. Soil to the depth of six inches was then placed on the benches, covering the pipes out of sight.

When the right conditions were secured in each of the beds for transplanting plants and sowing seed, experiments were begun, the results of which are given in the following pages.

Parsley.

On December 20, 1892, eight rows of moss-curled parsley seed were sown in beds 1 and 2, house A, five in bed 1 in ordinary, and three in bed 2 in sub-irrigation. Also, on the same date, eight rows of fine double-curled parsley seed were sown in beds 1 and 2, house C; five rows in bed 2 in ordinary, and three in bed one in sub-irrigation. The first parsley was picked for market on February 2, 1893, in the sub-irrigated beds of houses A and C. When parsley was ready for market in these beds, that in the surface-irrigated beds was not over one-third grown.

The plate shows a photograph of the two varieties of parsley grown in the respective beds. Bunches I and IV. represent the fine double-curled variety from beds 1 and 2, house C. Bunch I shows the average size in the five rows in surface-irrigated bed, and is about

one-half grown, while IV. presents the same variety in the sub-irrigated portion of the bed, out of which the largest had already been marketed. Bunches II. and III. represent the moss-curled parsley from beds 1 and 2, house A. Bunch II. gives the size of that in the five rows in surface-irrigated bed, while III. represents the same variety from the three rows in the sub-irrigated portion. The difference in maturity of parsley from seed, therefore, was very marked in favor of sub-irrigation. After the parsley in the surface-irrigated beds once reached maturity, there was no perceptible difference in its growth from that in the sub-irrigated bed.

Parsley is grown for its leaves, which are used in garnishing meats, etc.; therefore, only the leaves are picked off and these are generally sold in bunches, as shown in the plate. Immediately after the leaves are picked for market, the roots send forth a new growth. Bunches I. and II. are from the surface-irrigated and III. and IV. from the sub-irrigated beds.

Tomato Plants.

On March 28th, tomato plants, which were grown from seed sown on the 20th of December, and handled on January 28th, were placed in permanent beds. These tomatoes were all pruned, allowing a crop of lettuce to grow underneath them, thus receiving a double crop from the same area. For the experiment, bed 4, house A, was selected for surface, and bed 3, house B, for under-surface watering. While bed 4, house B, was used as a second check to bed 3. All the blossoms were hand-pollinated two or three times a week. The plants were placed 18 inches apart each way, and trained to one main stem. Each was held in place by a strong cord stretched from the base of the plant to the rafter of the greenhouse directly above, to which the plant was tied as it grew. This cord was kept in position by tying it to a small nail tacked in the rafter, while a peg stuck in the soil at the base of the plant served as a fastener at the other end. The plants were labeled and numbered consecutively in both beds, so that notes could be taken for each plant. Plants were selected with reference to similarity in size, struct ure, etc. They were transplanted somewhat later than they would have been, had we not been delayed a little by the tardy completion of the houses. The question of earliness, however, does not detract from the value of the experiment, for, although perhaps the weight of the fruit was not as great as it would have been had the vines been given more time, yet the comparative values of the beds were the same. All the fruit, of course, did not ripen at one time; therefore, it was necessary that the fruit be picked and weighed as it ripened, each plant being fully credited in the notes. When the experiment was concluded, the sum of the various weights gave the total product from each vine. The following tables show the comparative test of beds 4, house A, and 3, house B, above referred to.

4 HOUSE A SURFACE IRRIGATION.	Canada Victor.	Beauty.	Smooth Red.	Perfection.	Acme.	Conquer.	Octamus.
	Weight.	*Weight.*	*Weight.*	*Weight.*	*Weight.*	*Weight.*	*Weight.*
	2 lb 14 oz.	1 lb 6 oz.	2 lb 3 oz.	1 lb 6 oz.	10 oz.	3 lb 2 oz.	1 lb
	1 lb 5 oz.	11 oz.	2 lb 5 oz.	1 lb 6 oz.	1 lb 3 oz.	2 lb 1 oz.	14 oz.
	3 lb 2 oz.	1 lb 2 oz.	1 lb 3 oz.	13 oz.	1 lb 14 oz.		2 lb
	2 lb 13 oz.	1 lb	13 oz.		1 lb 3 oz.		2 lb 13 oz.
	3 lb	1 lb 10 oz.			3 lb 11 oz.		3 lb
	1 lb 13 oz.	2 lb 2 oz.			2 lb 6 oz.		
	8 oz.				1 lb 2 oz.		
	2 lb 10 oz.						
Average.....	2 lb 4 oz.	1 lb 5 oz.	1 lb 10 oz.	1 lb 3 oz.	1 lb 14 oz.	2 lb 9 oz.	1 lb 15 oz.

Beds. VARIETIES.

3 HOUSE SUB-IRRIGATION.	Canada Victor.	Beauty.	Smooth Red	Perfection.	Acme.	Conquer.	Octamus.
	Weight.	*Weight.*	*Weight.*	*Weight.*	*Weight.*	*Weight.*	*Weight.*
B	1 lb 8 oz.	1 lb 6 oz.	3 lb 5 oz.	2 lb	2 lb 2 oz.	3 lb 11 oz.	3 lb 5 oz.
	2 lb 10 oz	11 oz.	2 lb 8 oz.	1 lb 6 oz	2 lb 8 oz.	1 lb 8 oz.	1 lb 3 oz.
	2 lb 11 oz.	1 lb 8 oz.	2 lb 2 oz	2 lb 2 oz	3 lb 6 oz.		
	3 lb 6 oz.	3 lb 8 oz	2 lb 3 oz				
			1 lb 13 oz				
			4 lb 3 oz.				
Average.....	2 lb 9 oz.	1 lb 12 oz.	2 lb 11 oz	1 lb 13 oz.	2 lb 11 oz.	2 lb 9 oz.	2 lb 4 oz.

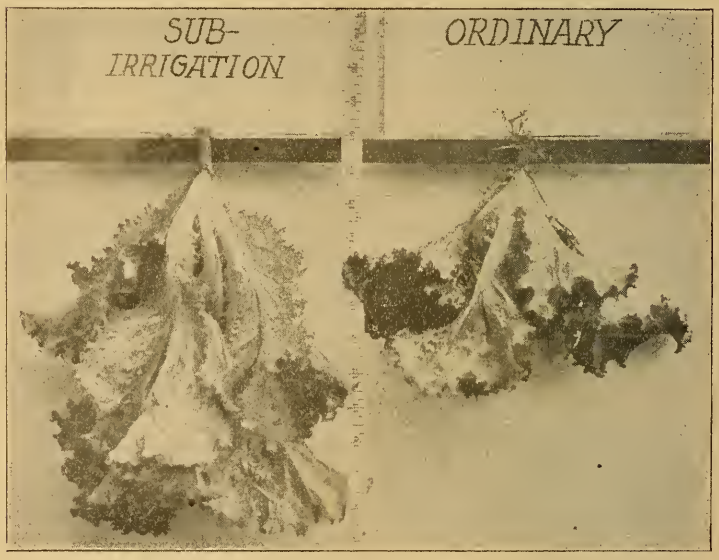
Individuality in plants varies, and experimental results can be relied upon only when a general average is taken. In a majority of cases, although the individual plants run comparatively evenly in each bed, as is found to be the case from the tables, nevertheless it does not necessarily hold true that the bed showing the greatest average always has the individual plants of the greatest weight. This is shown to be the case with the Acme variety, for one plant, in bed 4, house A, happened to produce even more fruit than any of those in bed 3, house B, of the same variety. This was an exceptional case, as is shown by the remaining varieties. The fact of its possibility is accepted as a natural occurrence by those who have had experience with plants. The averages, therefore, of a number of plants of the same variety establish their individual value. The comparative values found in the tables show the marked superiority of the method of sub-irrigation.

RADISHES.

VARIETY.	Sub-Irrigation.				Ordinary Irrigation.					
	Bed 2 House A.		Bed 1 House C.		Bed 1 House A.		Bed 2 House C.		Bed 3 House A.	
	Total Weight.	*No. Mktble.*	*Weight.*	*No. Mktble.*	*Weight.*	*No. Mktble.*	*Weight.*	*No. Mktble.*	*Weight.*	*No. Mktble.*
Olive Carmine. (Turnip-rooted).	1 lb 14 oz.	50	1 lb 3 oz.	29	2 lb	55	1 lb 8 oz.	50	1 lb 5 oz.	40
Early Short Top. (Long-rooted).	2 lb 10 oz.	24	4 lb 10 oz.	36			3 lb 13 oz.	19	2 lb	12
Early Bl'd Tur. (Turnip-rooted).	1 lb 3 oz.	12	2 lb 2 oz.	26	2 lb 6 oz.	23	2 lb 3 oz.	23	1 lb 2 oz.	12

The effects of the two methods of irrigation upon the growth of radishes are fairly shown in the table above, in which both the long and turnip-rooted varieties are used as examples. On the whole, no marked difference was observable in the productiveness of the turnip-rooted varieties in either bed. The effect was noted to be very beneficial in the case of the long-rooted radishes in weight, maturity and number marketable.

Lettuce.



Hanson.

No crop seems to be more affected by sub-irrigation than does that of lettuce. During the past winter, three crops of lettuce were grown in each of the larger portions of the various beds in the forcing-houses. The first two were given the entire space, while the last was grown under tomato plants, which were pruned and which served as a shade to protect the lettuce from the extreme heat of the sun in early spring. Notes were taken frequently and at each harvesting, the crops were weighed and results recorded. In addition to weight as an evidence of the superiority of the method of sub-irrigation, height, quality, earliness, etc. are also important points of proof.

The first crop was at least 25 per cent. better in the sub-irrigated beds, and was ready for market from ten days to two weeks before that in the other beds. At this time, one was nine inches and

the other 11½ inches high. The difference, therefore, in four weeks growth was a gain of 2½ inches in favor of sub-irrigation.

Frankfort Head.

The second crop was even more marked in its differences than the first. The accompanying photographs of lettuce exemplify the comparative merits of the two systems of watering with as many varieties of lettuce,—the Boston Curled, the Hanson, and the Frankfort Head. In the case of the Frankfort Head, the small heads were formed as perfectly as the large ones. With the open-headed varieties it is different; their maturity is considered reached when they have attained the desired size. One point in favor of sub-irrigated beds with lettuce is that it is ready for cultivation at all times, while the surface-watered beds are liable to contain more or less moisture, rendering cultivation less frequent. The cultivation of lettuce is for the most part performed during its younger stages, for as it matures, the more it fills up space, and the harder it is to manipulate the tools for cultivation. Sub-irrigated lettuce contains less chlorophyl; therefore is lighter in color.

Boston Curled.

Damping Off.

A comparative test of the various beds with reference to the damping off of the plants soon after transplanting is shown in the accompanying table. The plants were affected about equally by the disease in each instance, making the proportion between sub-irrigation and surface-watering as ten is to eleven.

VARIETY.	SUB-IRRIGATION			NON-IRRIGATION.		
	Bed 2, House A.	Bed 2, House C.	Bed 3, House B.	Bed 1, House A.	Bed 1, House C.	Bed 4, House B.
Black Seeded Simpson,			1			1
Hanson,			2	1		2
Frankfort Head,		6				
Boston Curled,	1					2
Grand Rapids,				1	4	
Total,	1	6	3	2	4	5

Lettuce Rot.

The lettuce rot, which appeared to a marked extent in the surface-watered beds was apparently absent in the sub-irrigated beds. The disease was first noticed at time of marketing at which time it could not be detected in the other beds. During the growth of the second crop, it became very troublesome, and some of the varieties in the surface-watered beds required marketing before they were fully grown, while in the under-surface watered beds, the disease was completely held in check.

Spinach

A slight difference was shown in earliness of maturity in favor of sub-irrigation. The plants started their seed stalks from one to two weeks earlier than those in ordinary irrigation.

Beets.

The turnip-rooted varieties of beets were placed in each of the beds. No marked difference was noticeable in either instance as the production was nearly equal in the beds. Beets take considerable time to mature in the greenhouse and hence are not a profitable crop as regards the vegetable itself. The comparison of the results from the same variety in ordinary and sub-irrigation, after having been transplanted 65 days, was: 16 beets in the former, weight 1 lb. 4 oz.; fifteen beets in the latter, weight, 1 lb. 2 oz.

Practical Conclusions.

The question of sub irrigation in the greenhouse is one worthy of consideration by all who have interests at stake in the pursuit of floriculture or forcing of vegetables. The exact merits of the method, whether used in or out of doors, cannot be arrived at until tested generally. We can easily see how its use might, in the hands of the inexperienced, be even misleading. The water is taken up by the soil through capillary attraction, which requires some time for complete action. The conditions are not normal if more water is used than is necessary, or if the requisite amount is lacking. Good judgment on the part of the operator is important. Thus it is with surface irrigation. In proportion as good judgment is exercised, good results will be secured.

Now, one point which the writer wishes to emphasize is that in sub irrigation, better results are obtained on account of its being a more complete system of watering. It has been our experience that in the majority of cases where plants in beds were not doing well, and where no external cause could be attributed, examination revealed the fact that the trouble was due to inefficient watering. In many cases the soil at a depth of three or four inches would be either dry and porous or baked hard. In numerous greenhouses visited the past year, we frequently noticed spots or portions of beds which seemed to remain dormant, although the conditions were apparently the same as those of the remaining por-

tions of the beds. On examination, however, the cause was found to be inefficient watering. Now, when we stop to think that capillary attraction is one of Nature's ways in which moisture travels, it is evident that sub-irrigation is the more natural method of applying water to the soil. For an experiment, we took two similar beds of dry soil, using the methods of surface and under-surface irrigation. While watching the results, we found that if the water was insufficient to moisten the whole of the bed, it did not penetrate perhaps over half way in the case of surface watering, and thus only the upper portion of the soil was of the right moisture. On the other hand, in the case of under-surface watering, the water was applied at the bottom of the bed, and capillary attraction caused it to ascend only half way. The difference between the two beds now is that one has the appearance of being in the right condition for seed or transplanted plants, while the other has not yet that appearance The condition in the one instance is deceiving, while in the other it is not. More water must be added to the sub-irrigated bed to make right conditions, while it is not necessarily so in the other.

It is already a demonstrated fact that when we apply water to soils out of doors in summer under ordinary circumstances, the greater portion of it goes off in the atmosphere; and in order to give the plants the requisite amount of moisture about the roots, a superabundance of water must be used. In the greenhouse, the external conditions are the same to greater or less an extent, and the above laws, therefore, hold true. Now, if we can apply the water directly underneath the soil by sub-irrigation, we overcome to a great extent this evaporation. It was found to be a fact that these sub-irrigated beds required very little water in comparison with the others.

The saving of labor through sub-irrigation is almost inestimable. The expenditure of time in watering was as follows: in the case of under-surface irrigation, the water was dipped out of a tank and poured into a funnel, through which it entered the various portions of the bed. On the other hand, in surface irrigation, the water was dipped out and applied by a sprinkling can, containg either a rose spray or a spout long enough to reach all sections of the bed. In the former case, the size of the plants did not matter, while in the latter, the more mature the crop, the more time it required for watering. Again, the sub-irrigated beds did not require watering over once or, at the outside, twice a week. While, generally speaking, the other beds were watered daily.

The idea that a water-tight bed is detrimental to plant growth on account of lack of drainage is overcome, we believe, in the fact that the pipe or tiles receive the excess of water, which, in a bed not water-tight, would leak out at the bottom, thus making it serve a double purpose. If the soil contains too much moisture, it serves as a reservoir; if not enough, it imparts the amount necessary for good conditions. In either case, the pipe or tiles act as a safety-valve. These openings underneath the soil allow free access of air, render plant food digestible, and act as a drain to water-soaked